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by

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Investigations of Drag-Reducing Mechanisms in Fish~~es~~

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Introduction

The primary objectives of this contract have been to supply NASA engineers with molds of the junction of fish fins and bodies, and other structures which might reduce drag associated with lift in fishes. Consequently, eleven dorsal and three pectoral fins were cast from specimens with both fixed and retractable fins, and skin molds were cast from an additional four specimens. These molds have been provided to NASA to initiate wind-tunnel studies of drag. Furthermore, collection of morphometrics and body surface area measurements were continued with the collection of morphometeric data from 70 specimens and surface areas from 36 specimens. Whole specimens preserved during this contract include two specimens of the uncommonly caught *Carcharhinus brevipinna* (spinner shark) and a single specimen of *C. limbatus* (blacktip shark). Both species are considered to be strong fast swimmers.

Methods

The sharks and other specimens collected during this study were obtained from longline cruises conducted during the summers of 1986 and 1987 by the Virginia Institute of Marine Science and from the Virginia Beach Sharkers Club's annual tournament at Rudee Inlet. As in previous years, specimens collected and returned to the lab were preserved in 10% formalin. A single specimen of *C. brevipinna* was frozen and returned to the lab. Gross morphometerics, body surface areas, and fin molds were taken from fresh specimens while still in the field to minimize distortion that normally occurrs during preservation.

Body surface area was measured consistent with the techniques described in earlier contract reports. Surface quadrants; dorsal head, dorsal body, ventral head. ventral body, caudal tail and fins, were covered with polyethelene sheeting of known density and were returned to the lab and weighed to the nearest 0.1 gram. Subsequent surface areas were then calculated from the equation

AREA = DENSITY X WEIGHT

Dorsal and pectoral fins were cast using a commercially available polyester resin manufactured by the Dynatron/Bondo Corp. and sold under the brand name of Bondo. Bondo is comprised of a polyester resin and styrene monomer that when mixed with a cream hardener, sets up in a matter of minutes. Utilizing fresh specimens, the target area was first covered with petroleum jelly to facilitate the removal of the finished mold. The premixed resin was then applied to the surface and held in place with aluminum strips. Upon hardening, approximately 10 - 15 minutes, the mold was then easily removed with a steady even pressure along the base. Subsequent, molds were tagged with species name, total length and date of casting. In September 1987, Nasa provided us with a silicone-based rubber compound manufactured by General Electric called RTV 60. This material was being prelimminarily tested to examine the possibility of molding the scale structure directly from the skin. Here again, the procedure consisted of applying the premixed compound to a clean, dry surface of the body. Four casts of this type were completed, two here at VIMS with Mike Walsh's supervision, and two from fresh specimens while offshore.

Results and Discussion

Surface areas were determined for Sphyrna lewini, Carcharhinus plumbeus, C. limbatus, C. brevipinna, C. leucas, C. limbatus, C. altimus, Mustelus canis, Squalus acanthias and Odontapsis taurus. The addition of three surface ares for C. plumbeus increased the sample size to thirteen and filled in some gaps in the specimen length range. For the first time, regression equations were fitted to C. obscurus, C. limbatus, G. cuvieri, and O. taurus. Regression slopes ranged from 33.4 to 164 sq.cm. per centimeter increase in standard length, with G. cuvieri increasing the fastest with growth (Table I). The remaining surface areas represent only a limited number of specimens for each species and more data needs to be collected before additional insight into surface area diversity in sharks can be gained.

Fin molds provided to NASA represent six species encompassing a variety of swimming stratagies. Furthermore, a couple of species included a sufficient size range for insight into ontogenetic changes in fin position.

Because we first developed our fin molding technique during the course of the present contract, the quality of molds (suitability of molds for engineering studies) improved during the course of this study.

Presently, we are awaiting feedback from NASA engineers as to the results of engineering studies on both the fin filleting molds and the morphology of scalloped trailing edges of shark fins supplied to NASA during an earlier phase of the contract. We are unable to test further hypotheses concerning concerning the drag reducing properties of these structures until the results of NASA engineering studies are available.

Table I. Linear Regressions Predicting Surface Area From Total Length

Carcharhinus plumbeus
n = 13
Y = -4766.2 + 100.6X**
R = .923

Carcharhinus obscurus
n = 4
Y = -4947.8 + 97.2X*
R = .994

Carcharhinus limbatus
n = 5
Y = 393.6 + 33.4X*
R = .882

Carcharhinus altimus
n = 6
Y = -8140.1 + 119.4X**
R = .907

Galacerdo cuvieri
n = 4
Y = -15860.7 + 164**
R = .992

Odontapsis taurus
n = 5
Y = -3309.6 + 79.7X**
R = .992

Mustelus canis
n = 6
Y = -2021.6 + 48.5X**
R = .942

Statistically significant
** 0.01 alpha level
* 0.05 alpha level

Material Collected 1986 - 1987

GENUS SPECIES		DATE COLLECTED	SL	M	SA	A	B	C	D	E	F	G
Carcharhinus	plumbeus	6/VI/86	103	X	X							
"	"	6/VI/86	83	X	X							
"	"	9/VI/86	172	X		X	X	X	X	X	X	al
"	"	31/VII/86			X	X		X				al
"	"	8/VI/87	159	X								
"	"	8/VI/87	158	X								
"	"	9/VI/87	148	X								
"	"	9/VI/87	65	X								
"	"	13/VI/87	154	X								
"	"	13/VI/87	163	X								
"	"	13/VI/87	170	X								
"	"	8/VII/87	75	dorsal fin mold								
"	"	8/VII/87	99	dorsal fin mold								
"	"	8/VII/87	110	dorsal fin mold								
"	"	8/VII/87	167	dorsal fin mold								
"	"	9/VII/87	111	dorsal fin mold								
Carcharhinus	altimus	23/IX/87	109	X	X	X	X	X	X	X		fr
Caraharhinus	leucas	9/VI/86	160	X	X	X	X					al
Carcharhinus	falciformis	29/VII/86	141			X						al
Carcharhinus	limbatus	9/VI/87	102	X	whole specimen							al
"	"	28/VII/87	89X	X	X	X	X	X	X			al
"	"	28/VII/87	95	X								
"	"	28/VII/87	104	X	X	X	X	X	X			al
"	"	28/VII/87	104	X	X	X	X	X	X			al
"	"	28/VII/87	107	X	X	X	X	X	X			al
"	"	28/VII/87	98	X	X	X	X	X	X			al
"	"	28/VII/87	101	X								
Carcharhinus	brevipinna	13/VI/87	140	X	whole specimen							al
"	"	28/VII/87	92	X	whole specimen							fz
"	"	28/VII/87	117	X	X	X	X	X	X	X		al
Carcharhinus	obscurus	14/VI/87	175	X								
"	"	13/VI/87	183	X								
"	"	13/VI/87	175	X								
"	"	13/VI/87	169	X								
"	"	22/IX/87	180	X	X	X	X	X	X	X		fr
"	"	24/IX/87	141	X	X	X	X	X	X	X		fr
"	"	25/IX/87	160	X	X	X	X	X	X	X		fr
"	"	24/IX/87	132	X	X	X	X	X	X	X		fr

GENUS SPECIES	DATE COLLECTED	SL	M	SA	A	B	C	D	E	F	G
Mustelus canis	5/V/86	93	X	X							
" "	5/V/86	62	X	X							
" "	5/V/86	51	X	X							
" "	5/V/86	78	X	X							
" "	5/V/86	65	X	X							
" "	5/V/86	98	X	X							
Negaprion brevirostris	14/V/87	188	X								
Odontapsis taurus	13/VI/87	184	X								
" "	13/VI/87	184	X								
" "	13/VI/87	160	X	X							
" "	13/VI/87	177	X								
" "	13/VI/87	203	X								
" "	13/VI/87	175	X	X							
" "	13/VI/87	202	X								
" "	5/V/86	108	X	X							
" "	5/V/86	82	X	X							
Syphrna lewini	6/V/86	92	X	X	head						al
" "	21/VIII/86	98	X	X	X	X	X	X	X	hd	al
" "	22/6/86	168	X	X	head						al
" "	13/VI/87	160	X								
" "	13/VI/87	156	X								
" "	13/VI/87	164	X								
" "	13/VI/87	164	X								
" "	14/VI/87	179	X								
" "	14/VI/87	180	X								
" "	14/VI/87	162	X								
" "	25/IX/87	173	X	X	X	X	X	X	X		fr
Galrocerdo cuvieri	31/VII/86			X	X	X					al
" "	13/VI/87	153	X								
" "	13/VI/87	179	X								
" "	13/VI/87	190	X								
" "	13/VI/87	182	X								
" "	13/VI/87	272	X								
" "	13/VI/87	241	X								
" "	13/VI/87	212	X								
" "	13/VI/87	277	X								
" "	13/VI/87	230	X								
" "	13/VI/87	175	X								
" "	22/IX/87	218	X	X	X	X	X	X	X	X	fr
" "	22/IX/87	185	X	X							
" "	22/IX/87	151	X	X							

GENUS SPECIES	DATE COLLECTED	SL	M	SA	A	B	C	D	E	F	G
Isurus oxyrinchus	13/VI/87	97	X		X	X				X	al
" "	13/VI/87	93	X		X	X				X	al
" "	13/VI/87	98	X		X	X				X	al
Squalus acanthias	5/V/86	76	X	X							
Rhizoprionodon terraenovae	28/VI/87	71	whole specimen								al
Alopias superciliosus	24/IX/87	202	X	X							
Tunnus albacores	30/VII/86		X	X	X	X				X	al
Xiphias gladius	30/VII/86		X	X	X	X				X	al

SL Standard length
M Morphometric measurements
SA Surface area
A Dorsal I
B Dorsal II
C Pectoral fin
D Pelvic fin
E Anal fin
F Caudal fin
G Preservation; al alcohol, fr formalin, fz frozen.